Patent
Attorney's Docket No. 003300-688

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

UTILITY PATENT
APPLICATION TRANSMITTAL LETTER

Box PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Enclosed for filing is the utility patent application of ALAN G. JACK, BARRIE MECROW, and ÖYSTEIN KROGEN for INDUCTION MACHINE STATOR.

Also enclosed are:

[X] 1 sheet(s) of [X] formal [ ] informal drawing(s);

[X] a claim for foreign priority under 35 U.S.C. §§ 119 and/or 365 is [X] hereby made to PCT/SE99/00614 filed in the International Office on April 19, 1999, and Swedish Application No. 9801402-1, filed April 21, 1998 ;

[X] in the declaration;

[X] a certified copy of the priority document;

[ ] a General Authorization for Petitions for Extensions of Time and Payment of Fees;

[ ] an Assignment document;

[X] an Information Disclosure Statement; and

[X] Other: Preliminary Amendment and Claim for Convention Priority.

[X] An [ ] executed [X] unexecuted declaration of the inventor(s)

[X] also is enclosed [ ] will follow.

[ ] Please amend the specification by inserting before the first line the sentence --This application claims priority under 35 U.S.C. §§ 119 and/or 365 to _ filed in _ on _; the entire content of which is hereby incorporated by reference.--

[ ] A bibliographic data entry sheet is enclosed.

[ ] Small entity status is hereby claimed.

[X] The filing fee has been calculated as follows [X] and in accordance with the enclosed preliminary amendment:

CLAIMS					
	NO. OF CLAIMS		EXTRA CLAIMS	RATE	FEE
Basic Application Fee					$710.00 (101)
Total Claims	20	MINUS 20 =	0	× $18.00 (103) =	---
Independent Claims	2	MINUS 3 =	0	× $80.00 (102) =	---
If multiple dependent claims are presented, add $270.00 (104)					---
Total Application Fee					$710.00
If small entity status is claimed, subtract 50% of Total Application Fee					---
Add Assignment Recording Fee $ if Assignment document is enclosed					---
TOTAL APPLICATION FEE DUE					**$710.00**

[ ] This application is being filed without a filing fee. Issuance of a Notice to File Missing Parts of Application is respectfully requested.

[X] A check in the amount of $ 710.00 is enclosed for the fee due.

[ ] Charge $ _____ to Deposit Account No. 02-4800 for the fee due.

[X] The Commissioner is hereby authorized to charge any appropriate fees under 37 C.F.R. §§ 1.16, 1.17 and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800. This paper is submitted in duplicate.

Please address all correspondence concerning the present application to:

Benton S. Duffett, Jr.
BURNS, DOANE, SWECKER & MATHIS, L.L.P.
P.O. Box 1404
Alexandria, Virginia 22313-1404.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

Date: October 10, 2000

By: _____
Benton S. Duffett, Jr.
Registration No. 22,030

P.O. Box 1404
Alexandria, Virginia 22313-1404
(703) 836-6620

Patent
Attorney's Docket No. 003300-688

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
	)	
ALAN G. JACK	)	Group Art Unit: Unassigned
BARRIE MECROW	)	
ÖYSTEIN KROGEN	)	Examiner: Unassigned
	)	
Application No.: Unassigned	)	
	)	
Filed: October 10, 2000	)	
	)	
For: INDUCTION MACHINE STATOR	)	
	)	

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

This Application is a continuation of International Application No. PCT/SE99/00614, filed April 19, 1999.

Prior to examination, please amend as indicated.

In the Abstract:

Please add the Abstract of the Disclosure that is submitted on a separate sheet.

In the Specification:

Page 1, before line 1, insert the following paragraph:

--This is a continuation of International Application No. PCT/SE99/00614, filed April 19, 1999, and claims priority for the filing of Swedish Application No. 9801401-2, filed April 21, 1998.--

In the Claims:

Claim 3, line 1, delete "or 2".

Claim 4, line 1, delete "any one of claims 1-3" and insert --claim 1--.

Claim 7, line 1, delete "or 6".

Claim 8, line 1, delete "any one of claims 1-7" and insert --claim 1--.

Claim 9, line 1, delete "any one of claims 1-8" and insert --claim 1--.

Claim 10, line 1, delete "any one of claims 1-9" and insert --claim 1--.

Please add the following new Claims 11 to 20:

--11. A stator as claimed in claim 2, wherein each stator section (2, 3) has the same number of teeth (6, 7).

12. A stator as claimed in claim 2, wherein each stator section (2, 3), at least partly, is made of a magnetic powder.

13. A stator as claimed in claim 3, wherein each stator section (2, 3), at least partly, is made of a magnetic powder.

14. A stator as claimed in claim 11, wherein each stator section (2, 3), at least partly, is made of a magnetic powder.

15. A stator as claimed in claim 6, wherein the adjoining parts of the yoke (4, 5) extend axially past the teeth (6, 7) at least at one of the axial sides thereof.

16. A stator as claimed in claim 2, wherein the tips (11) of the teeth (6, 7) extend axially past the main part of the teeth at least at one of the axial sides thereof.

17. A stator as claimed in claim 3, wherein the tips (11) of the teeth (6, 7) extend axially past the main part of the teeth at least at one of the axial sides thereof.

18. A stator as claimed in claim 2, wherein each tooth (6, 7) has a rounded profile.

19. A stator as claimed in claim 3, wherein each tooth (6, 7) has a rounded profile.

20. A stator as claimed in claim 2, wherein the stator sections (2, 3) are separated axially.--

REMARKS

The present Amendment adds an Abstract of the Disclosure on a separate sheet and eliminates the use of multiple dependency.

An Information Disclosure Statement and a Claim for Convention Priority are being filed herewith.

The examination and allowance of this Application are respectfully requested.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: Benton S. Duffett Jr.

Benton S. Duffett, Jr.
Registration No. 22,030

P.O. Box 1404
Alexandria, Virginia 22313-1404
(703) 836-6620

Date: October 10, 2000

INDUCTION MACHINE STATOR

Technical field

The present invention is generally related to electrical induction machines and more specifically to a stator for an induction machine.

Background of the invention and prior art

Conventionally, the stator assembly of an electrical machine has a stator core formed of a stack of steel laminations. As an alternative to the use of steel laminations, the stator core may be formed from iron powder, as exemplified by U.S. Patent No. 4,947,065 disclosing a stator moulded in one-piece, and by International Patent Application WO95/12912 disclosing a stator comprising a plurality of separate and substantially identical parts.

By its very nature any compacted, non-sintered material will not be fully dense. This means that soft iron powder currently available will have a permeability that is lower than the permeability obtainable with steel laminations. However, magnetic powder composites could offer advantages such as isotropic magnetic behaviour, reduction in iron losses at high frequencies, improved thermal characteristics and flexible design and assembly.

The use of single tooth geometry could give rise to large benefits when it comes to thermal and manufacturing properties of electrical machines. However, the single tooth winding geometry will also give rise to a different spectrum of harmonics of the armature field, compared to a standard winding arrangement. These higher order fields, which may travel around the airgap at different speed compared to the working harmonics, will induce eddy currents in the stator and the rotor.

In a synchronous machine, these higher order fields have substantially no influence on the torque, while in an induction machine they will produce additional torque

at synchronous speeds different to the main speed and thereby result in reductions and/or dips in the torque-speed characteristic and extra rotor losses.

In a traditional induction machine, this is avoided by distributing the windings in slots, but this is not possible if one wants to have a polyphase winding made from single tooth sections.

JP-A-7298578 discloses an alternative for the single tooth winding geometry. More specifically, the stator is divided into two parts along its axis and the two parts are shifted an angle of 0-120° electrical, preferably 90° electrical. However, this shift only cancels the second harmonics and therefore further measures are necessary. According to this reference, a fixed tooth width (or slot opening width) to tooth pitch ratio is necessary to cancel higher order even harmonics. This results in less geometrical freedom for the motor design. The conventional use of slot skew to reduce cogging also will be affected by the constricted motor design parameters.

Summary

One object of the present invention is to provide a stator for an electrical induction machine which benefits from the use of the single tooth geometry and at the same time corrects reductions and/or dips in the torque-speed characteristic and the extra rotor losses without resort to the features disclosed in JP-A-7298578.

This object is achieved by a stator as claimed in the appending claim 1. Thus, by dividing the stator into an even number of stator sections at different axial positions, each section having a plurality of circumferentially separated, radially oriented teeth and each tooth having a single winding, the effect of other harmonics than the working harmonics may be reduced in that the stator sections are mutually phase shifted by substantially 360°/n electrical ± an angle related to skew and in that n/2 of the stator sections have their electrical supplies shifted by 180° electrical.

The effect produced by several stator sections on a single rotor is substantially the same as a distributed winding. This leads to the cancelling of a large fraction of the higher harmonics while keeping the benefits of single tooth windings, i.e. high slot fill factor, and simple manufacturing and assembling.

The two stator sections will only be separated by a small air-gap of the order of the teeth opening, preferably obtained by making each stator section at least partly from a magnetic powder. The stator sections should at least have different axial positions; i.e. they might even be juxtaposed. Each stator section will contain the same harmonics, but the phase shifting of them will, seen from the rotor conductor bars, cancel a large fraction of unwanted higher order harmonics.

Brief description of the drawings

FIG. 1 is an end view of a stator for a 4-pole 3-phase induction motor according to one embodiment of the present invention.

FIG. 2 is an axial cross-sectional view along lines II-II in FIG. 1.

Description of the preferred embodiment

Referring to FIGS. 1 and 2, a stator 1 of an induction motor is illustrated as having two axially separated stator sections 2 and 3. Each one of the stator sections has a yoke section 4 and 5, respectively; adjoining six circumferentially separated, radially extending teeth 6 and 7, respectively.

More precisely, each tooth 6 and an adjoining part of the corresponding yoke section 4 form a separate unit or segment 8. Similarly, each tooth 7 and an adjoining part of the corresponding yoke section 5 form a separate unit or segment 9.

The yoke sections 4 and 5 are physically phase shifted by 180° electrical ± an angle that is related to skew (not shown). Their electrical supplies are also shifted by 180° electrical. Further, the stator sections

2 and 3 are separated by a small air gap 10 so as to reduce the mutual influence of the magnetic fields in the two stator sections 2 and 3.

As a result, each stator section will contain the same harmonics, but the phase shifting of them will, as seen from the single rotor (not illustrated), cancel a large fraction of the unwanted higher order harmonics.

Assembling each of the stator sections 2 and 3 from the separate units 8 and 9, respectively, permits an easy winding of each unit of the stator 1.

The multiple separate units 8 and 9 (twelve in the current embodiment) are made of a soft magnetic powder composite material which is filled into a die, pressed to a desired shape and then heat treated at a relatively low temperature so as not to destroy the necessary insulating layer between the powder particles. This means that volume production of the separate units 8 and 9 is possible and results in no material waste and a finished pressed unit with high tolerances and little or no machining being required.

As shown for one unit 8 and one unit 9 in FIG. 2, the axial length of each tooth 6, 7 is less than the axial length of the adjoining part of the yoke section 4, 5. The extension of the yoke sections 4, 5 axially past the teeth 6, 7 is asymmetric on the two axial sides thereof and increases the active length of the core and reduces the iron losses and magnetising current such that a more efficient machine is provided. Further, the heat transfer from the windings to the stator is improved by the axial extensions of the yoke adjoining the coil turn parts outside the winding slots.

The above described design may be used for reducing the total winding length and thereby reduce the dimensions of the electrical machine with maintained performance.

As illustrated in the drawings, the tips 11 of the teeth 6 and 7 also extend axially past the main part of

the teeth on both axial sides thereof. The extension of the teeth tips allows a reduction in the air gap reluctance which produces a corresponding reduction in magnetising current. This offsets the deleterious effects of the relatively low permeability of powder iron.

A further advantage of using powder material is that the sectional tooth profile may be rounded or oval such that sharp bending of the coil turns is eliminated and the risk of penetration of the insulation at the corners is reduced. This allows thinner insulation to be used resulting in a substantial thermal benefit. The winding arrangement may comprise a non-overlapping winding on each tooth that simplifies the winding operation and allows very high packing factors to be achieved.

It should be noted that the rotor (not shown in FIGS. 1 and 2) of the induction motor preferably is of conventional design.

While only one embodiment of the present invention is described above, it is obvious to those skilled in the art that the several modifications are possible without departing from the spirit of the present invention.

Thus, the invention can be used in machines having an outer rotor instead of the exemplified inner rotor.

Further, the material of the stator may comprise laminations or a powder material combined with other materials, e.g. laminations, or the stator may be made by casting.

CLAIMS

1. A stator for an electrical induction machine, comprising an even number n of stator sections (2, 3) at different axial positions, each section having a plurality of circumferentially separated, radially extending teeth (6, 7) and each tooth having a single winding, wherein the stator sections are mutually phase shifted by substantially 360°/n electrical ± an angle related to skew, and then n/2 of the stator sections have their electrical supplies shifted by 180° electrical so as to reduce the effect of other harmonics than the working harmonics.

2. A stator as claimed in claim 1, wherein the even number n is 2, the stator sections (2, 3) being physically phase shifted by substantially 180° electrical ± an angle related to skew, and the two stator sections have their electrical supplies shifted by 180° electrical.

3. A stator as claimed in claim 1 or 2, wherein each stator section (2, 3) has the same number of teeth (6, 7).

4. A stator as claimed in any one of claims 1-3, wherein each stator section (2, 3), at least partly, is made of a magnetic powder.

5. A stator as claimed in claim 4, wherein each stator section (2, 3) is made of several separate units (8, 9), each unit comprising a tooth (6, 7) and an adjoining part of a yoke (4, 5) of the stator (1).

6. A stator as claimed in claim 5, wherein each unit (8, 9) also comprises one of said single windings.

7. A stator as claimed in claim 5 or 6, wherein the adjoining parts of the yoke (4, 5) extend axially past the teeth (6, 7) at least at one of the axial sides thereof.

8. A stator as claimed in any one of claims 1-7, wherein the tips (11) of the teeth (6, 7) extend axially

past the main part of the teeth at least at one of the axial sides thereof.

9. A stator as claimed in any one of claims 1-8, wherein each tooth (6, 7) has a rounded profile.

10. A stator as claimed in any one of claims 1-9, wherein the stator sections (2, 3) are separated axially.

11. An electrical induction machine having a rotor and a stator, wherein the stator comprises an even number n of stator sections (2, 3) at different axial positions, each section having a plurality of circumferentially separated, radially extending teeth (6, 7) and each tooth having a single winding, wherein the stator sections are mutually phase shifted by substantially 360°/n electrical ± an angle related to skew, and n/2 of the stator sections have their electrical supplies shifted by 180° electrical so as to reduce the effect of other harmonics than the working harmonics.

Abstract of the Disclosure

A stator (1) for an electrical induction machine comprises at least two stator sections (2, 3) at two different axial positions, each section having a plurality of circumferentially separated, radially extending teeth (6, 7) and each tooth having a single winding. The stator sections are mutually phase-shifted so as to reduce the effect of other harmonics than the working harmonics. In a stator having two separated stator sections, these are physically phase-shifted by 180° electrical ± an angle related to skew, and then have their electrical supplies also shifted by 180° electrical.

FIG 1

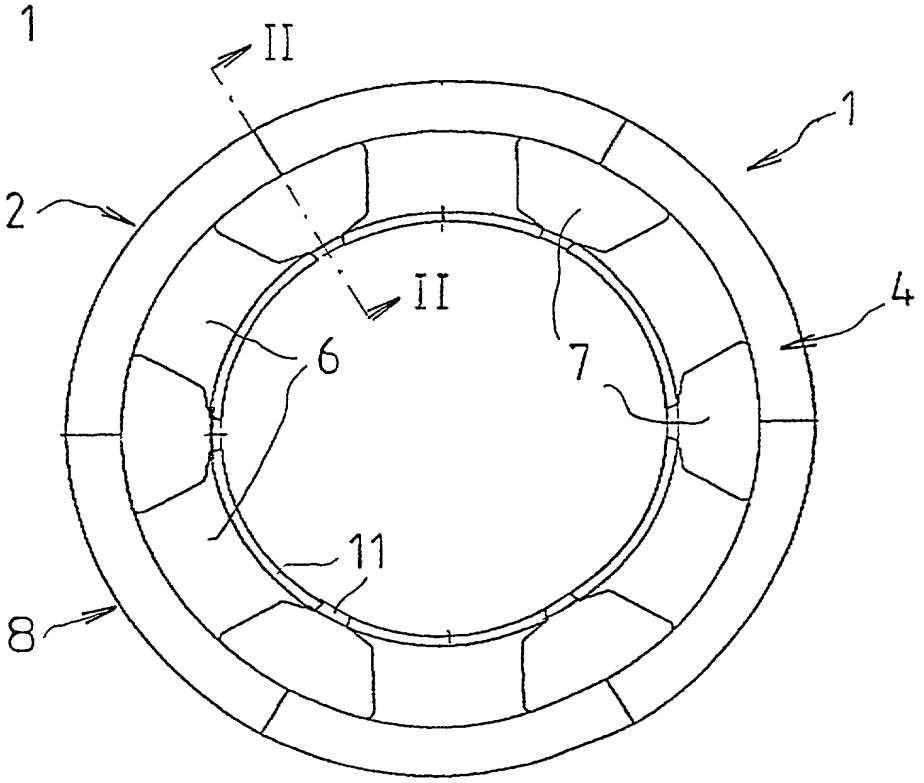
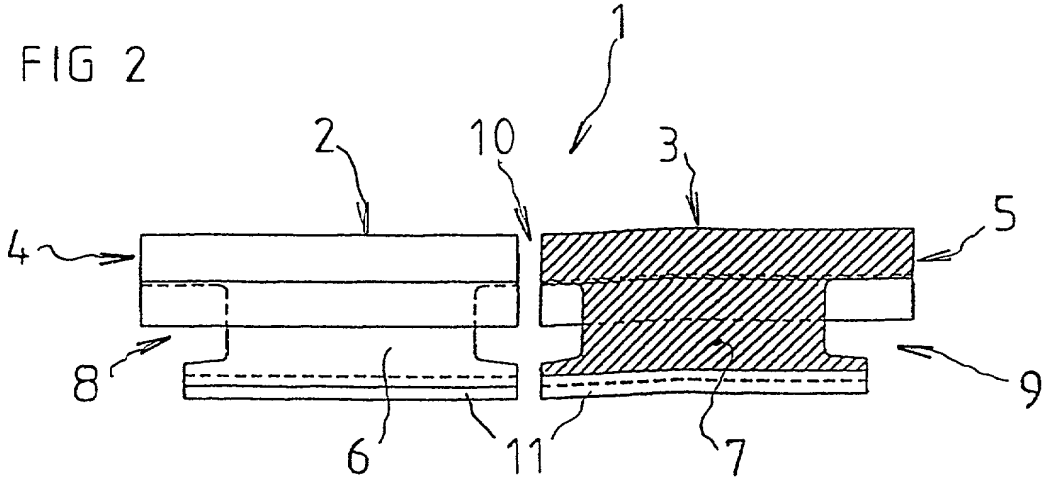


FIG 2



COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY **(Includes Reference to Provisional and PCT International Applications)**	Attorney's Docket No. 003300-688

As a below named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below next to my name;
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

INDUCTION MACHINE STATOR

the specification of which (check only one item below):

☒ is attached hereto.

☐ was filed as United States application
Number _____
on _____
and was amended
on _____ (if applicable).

☐ was filed as PCT international application
Number _____
on _____
and was amended
on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(e) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §119:

COUNTRY (if PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. §119
Sweden	9801401-2	21 April 1998	X Yes _ No
			_ Yes _ No
			_ Yes _ No
			_ Yes _ No
			_ Yes _ No

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

_____ _____
(Application Number) (Filing Date)

_____ _____
(Application Number) (Filing Date)

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONT'D) (Includes Reference to Provisional and PCT International Applications)	Attorney's Docket No. 003300-688

I hereby claim the benefit under Title 35, United States Code, §120 of any United States applications(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose to the Office all information known to me to be material to the patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. §120:

U.S. APPLICATIONS		STATUS *(check one)*		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO.	PCT FILING DATE	U.S. APPLICATION NUMBERS ASSIGNED (if any)			
PCT/SE99/00614	19 April 1999			X	

I hereby appoint the following attorneys and agent(s) to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and to transact all business in connection with international applications directed to said invention:

William L. Mathis	17,337	R. Danny Huntington	27,903	Gerald F. Swiss	30,113
Robert S. Swecker	19,885	Eric H. Weisblatt	30,505	Charles F. Wieland III	33,096
Platon N. Mandros	22,124	James W. Peterson	26,057	Bruce T. Wieder	33,815
Benton S. Duffett, Jr.	22,030	Teresa Stanek Rea	30,427	Todd R. Walters	34,040
Norman H. Stepno	22,716	Robert E. Krebs	25,885	Ronni S. Jillions	31,979
Ronald L. Grudziecki	24,970	William C. Rowland	30,888	Harold R. Brown III	36,341
Frederick G. Michaud, Jr.	26,003	T. Gene Dillahunty	25,423	Allen R. Baum	36,086
Alan E. Kopecki	25,813	Patrick C. Keane	32,858	Steven M. duBois	35,023
Regis E. Slutter	26,999	B. Jefferson Boggs, Jr.	32,344	Brian P. O'Shaughnessy	32,747
Samuel C. Miller, III	27,360	William H. Benz	25,952	Kenneth B. Leffler	36,075
Robert G. Mukai	28,531	Peter K. Skiff	31,917	Fred W. Hathaway	32,236
George A. Hovanec, Jr.	28,223	Richard J. McGrath	29,195		
James A. LaBarre	28,632	Matthew L. Schneider	32,814		
E. Joseph Gess	28,510	Michael G. Savage	32,596		

21839

and: none

Address all correspondence to:

21839

Benton S. Duffett, Jr.
BURNS, DOANE, SWECKER & MATHIS, L.L.P.
P.O. Box 1404
Alexandria, Virginia 22313-1404

Address all telephone calls to: Benton S. Duffett, Jr. at (703) 836-6620.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONT'D) (Includes Reference to Provisional and PCT International Applications)	Attorney's Docket No. 003300-688

FULL NAME OF SOLE OR FIRST INVENTOR ALAN G. JACK	SIGNATURE	DATE
RESIDENCE Hexham, Northumberland, United Kingdom	CITIZENSHIP United Kingdom	
POST OFFICE ADDRESS Milestone House, Allendale Road, Hexham, Northumberland NE46 2NB United Kingdom		
FULL NAME OF SECOND JOINT INVENTOR, IF ANY BARRIE MECROW	SIGNATURE	DATE
RESIDENCE Whitley Bay, Tyne and Wear, United Kingdom	CITIZENSHIP United Kingdom	
POST OFFICE ADDRESS 50 Haddington Road, Whitley Bay, Tyne and Wear, United Kingdom		
FULL NAME OF THIRD JOINT INVENTOR, IF ANY ÖYSTEIN KROGEN	SIGNATURE	DATE
RESIDENCE Höganäs, Sweden	CITIZENSHIP Sweden	
POST OFFICE ADDRESS Långarödsvägen, 26332 Höganäs, Sweden		
FULL NAME OF FOURTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE	CITIZENSHIP	
POST OFFICE ADDRESS		
FULL NAME OF FIFTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE	CITIZENSHIP	
POST OFFICE ADDRESS		
FULL NAME OF SIXTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE	CITIZENSHIP	
POST OFFICE ADDRESS		
FULL NAME OF SEVENTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE	CITIZENSHIP	
POST OFFICE ADDRESS		
FULL NAME OF EIGHTH JOINT INVENTOR, IF ANY	SIGNATURE	DATE
RESIDENCE	CITIZENSHIP	
POST OFFICE ADDRESS		